Kinematic Comparison of Team Handball Throwing With Two Different ArmPositions

Herbert Wagner, Michael Buchecker, Serge P. von Duvillard, and Erich Müller

Purpose: The aims of the present study were: (1) to compare the differences in the ball release speed and throwing accuracy between the ABOVE and SIDE throw; (2) to analyze kinematic differences of these two throwing techniques; and (3) to give practical applications to team handball coaches and players. Methods: Ball release speed, throwing accuracy, and kinematics were measured via the Vicon MX 13 (Vicon Peak, Oxford, UK) from 12 male elite right-handed team handball players. Results: Results of our study suggest that the two throwing techniques differ significantly ($P < .0073$) in the angles and/or angular velocities of the trunk (flexion, left tilt and rotation) and shoulder (flexion and abduction) of the throwing arm that result in a significantly different ball release speed ($1.4 \pm 0.8 \text{ m/s}; P < .001$) and that throwing accuracy was not significantly different. Conclusion: Our results indicated that the different position of the hand at ball release of the ABOVE and SIDE throws is primarily caused by different trunk flexion and tilt angles that lead to differences in ball release speed but not in throwing accuracy, and that the participants try to move their throwing arm similarly in both throwing techniques.

Keywords: biomechanics, throwing performance, ball release speed, throwing accuracy, angles, angular velocities

To score goals, team handball players utilized different throwing techniques, that is, standing throws, standing throws with run-up, jump throws or diving throws depending on their playing position and/or the positions of the defensive players. For the standing throw with run-up, which constitutes a basic throwing technique in team handball and is usually learned in the beginning, the position of the throwing arm varies during competition depending on the position of the defending players block. When the arms of the defensive player were held beside the body (Figure 1A), the throwing offensive player, who tries to score a goal, releases the ball above

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Figure 1 — Sequence of movement in team handball standing ABOVE (A) and SIDE (B) throw.
the arm of the defensive player to prevent blocking of the ball (ABOVE throw). When the arms of the defensive player were held above the head (Figure 1B), the offensive player throws the ball sideward of the defensive player by changing the position of the throwing arm at ball release (SIDE throw).

The basic throwing techniques in team handball have been analyzed previously; however, the different positions of the throwing arm were not described adequately. Kinematics of the standing throw with and without run-up in team handball were reported. The authors identified the ball release speed as the main performance factor determining the throwing movement. Van den Tillaar and Ettema found that the angular velocity of the internal shoulder rotation, the elbow extension angle at ball release, the maximal angular velocity of the elbow extension and the timing of the maximal pelvis external rotation angle contribute greatly to the ball release speed. Timing of the maximal angles was defined as the time before ball release. Wagner et al. analyzed jump throws in team handball between elite vs. low level players and found significant differences in ball release speed, maximal trunk flexion and rotation angular velocity and trunk flexion and shoulder internal rotation angular velocity at ball release.

However, the standing throw with run-up in team handball is characterized by a run-up after catching the ball with either one, two or three steps, depending on the game situation. In contrast to the steps before the ball is received, which are used to increase the horizontal velocity and/or to move to the right throwing position, the last step opens the arm cocking phase, where the throwing arm and the ball move backward (Figure 1A-1 and 1B-1). After planting of the left foot on the floor, the left knee is extended and the pelvis and trunk are rotated forward as fast as possible (Figure 1A-2, 1B-2). In the ABOVE throw, the trunk is bent to the left side and the throwing arm is moved forward above the head (Figure 1A-3). In the SIDE throw, the trunk is bent to the right and the throwing arm is moved forward beside the trunk (Figure 1B-3). After ball release, the right foot is moved to the front (Figure 1A-4) or to the side (Figure 1B-4) of the left foot (follow-through phase) to reduce the horizontal velocity after foot contact.

In absence of studies analyzing differences in performance and kinematics in team handball throwing with different arm positions we were dependent on the experience in team handball training and competition, video observations (Figure 1A and B) and other studies in team handball to form our hypotheses. Wagner et al. found that in competition elite team handball players used 62% ABOVE but only 38% SIDE throws. Less practice in training and competition and the differences in trunk and arm movement (Figure 1A and B) in the SIDE throw compared with the ABOVE throw lead to the hypothesis that ABOVE and SIDE throw differ significantly in ball release speed and throwing accuracy. In Figure 1A and B, it is clearly observable that ABOVE and SIDE throw differ in the trunk side tilt and it seems that the movements differ also in the shoulder abduction angle at ball release. It is not clearly observable if these two movements differ also in the pelvis rotation, trunk flexion and rotation, shoulder flexion and rotation and elbow flexion angles and angular velocities that contribute greatly to ball release speed. We hypothesize that ABOVE and SIDE throw differ significantly in upper body angles and angular velocities. The main component of the ABOVE and SIDE throw is the position of the ball (above head vs. side the trunk) at ball release. As shown in Figure 1A-1 and B-1 both throws appear to be similar in the initial phase of the throw and
differ afterward (Figure 1A-2 and B-2). The differences in kinematics depending on the movement phase could be determined statistically by the differences in the timing of the maximal angles and angular velocities as well as by the differences in the whole angle-time course. We hypothesize to find significant differences in the timing between the ABOVE and SIDE throw.

Therefore, the aims of our study were: (1) to compare the differences in the ball release speed and throwing accuracy between the ABOVE and SIDE throw; (2) to analyze differences in kinematics between these two throwing techniques; and (3) to give practical applications for team handball coaches and athletes.

Methods

Participants

Twelve elite male team handball players (age: 22.5 ± 3.7 y, body mass: 84.4 ± 10.5 kg, height: 1.87 ± 0.06 m, training experience: 10.3 ± 3.6 y), playing in the First, Second and Third Austrian and First Spanish and German Handball League (six of them are still members of the Austrian National Team) volunteered to participate in this study. All participants were physically healthy, in good physical condition and reported no injuries during the time of the study. The study was approved by the local ethics committee and all participants signed informed consent. To assure uniform comparison of the results, all participants were right-handed and we selected players from all four right-hand playing positions (left wing, pivot and backcourt left and middle player).

Experimental Design and Methodology

In this study, we compared two different throwing techniques (ABOVE vs. SIDE throw) in elite team handball players. The study was conducted during the regular team handball season to ensure that all participants were familiar with both throwing techniques in training and competition. In the testing situation we measured 1) ball release speed, 2) throwing accuracy (percentage of throws that missed the target and mean radial error), 3) maximal pelvis rotation, trunk flexion, left tilt, rotation, shoulder flexion, abduction, rotation and elbow flexion angle/angular velocity and timing as well as angle/angular velocity at ball release.

Test Protocol

After a general and team handball specific warm-up of 20 min, the participants performed 20 valid standing throws with run-up, 10 for each throwing technique. To reduce the influence of fatigue, the throwing technique was changed after 5 valid throws in random order with 1 min break between the throws. At the beginning of each throw, the participants were instructed to hold the ball still in both hands. After an acoustic signal, the participants performed a standing throw with a three step run-up with the throwing arm above the head (ABOVE) or side the trunk (SIDE). To ensure that the run-up speed did not influence the results, run-up speed was controlled by calculating the maximal horizontal velocity of the center of mass.9 The difference for all participants between the two throwing techniques
was smaller than 0.1 m·s⁻¹. Participants were instructed to throw the ball to the center (target point) of a square of 1 × 1 m, with maximal ball release speed and with maximal throwing accuracy. The horizontal distance of the target was 8 m and the target center was set at about eye level (1.75 m). A throw was valid if the ball hit the square and data was collected. For each throwing technique, the 6 throws with the highest ball release speed (main performance determining parameter) for each player were included in the calculation. For each variable the mean value of these 6 throws was calculated and used for statistical analysis.

**Kinematic Analysis**

The experimental set-up for kinematic analysis was conducted via Vicon MX13 motion capture system (Vicon Peak, Oxford, UK) including 8 cameras sampling at 250 frames per second. Each participant was marked with 39 reflective markers of 14 mm diameter on specific anatomical landmarks (Plug-In Gait Marker Set, Vicon Peak, Oxford, UK). Three-dimensional coordinates of the 39 markers were reconstructed with the Nexus software (Nexus 1.3, Vicon, Oxford, UK) and smoothed using cross validation splines. To calculate the joint center positions a three-dimensional model (Plug In Gait Model, Vicon Peak, Oxford, UK) dividing the body into lower and upper body models was used. The method of joint center, segments orientation and angle and angular velocity calculation was used as described in detail by Wagner et al. to analyze the jump throw in team handball. The accuracy of measurement of the model is described in Tilp et al. and the reliability of the kinematic variables in Ranson et al. Calculation of trunk flexion, left tilt and rotation, shoulder flexion, abduction and rotation as well as elbow flexion angle was the same as described in detail by Wagner et al. (Figure 2).

**Ball Release Speed, Throwing Accuracy and Timing**

To measure the ball release speed, the linear velocity of the center of the ball was calculated. The center of the ball was defined as the middle point of 2 markers that were positioned on the opposite sides of the ball. To determine the moment of ball release, the distance between the center of the ball and the hand marker (head of the second metatarsal) was calculated. This distance increases abruptly at ball release. Ball release was used to determine the time-frame for calculating angles and angular velocity. The time-frame was defined as the time lag 100 frames before and 25 frames after ball release, which was sufficient to calculate all relevant variables. Timing of the maximal angles and angular velocities was measured as time before ball release.

Throwing accuracy was defined by the percentage of the throws missing the target relative to all throws of each participant and the mean radial error. Mean radial error was termed as the distance of the ball impact point to the center of the target and was measured via Peak Motus 9.0 (Vicon Peak, Oxford, UK) using a digital video camera, operating at 120 frames per second. Mean radial error was calculated for all 6 selected throws of each participant. To exclude the missed throws and those 4 with lower ball release speed is a limitation of the study but ball release speed is the main performance factor determining the throwing movement and therefore we decided to calculate the mean radial error for just these 6 selected
Figure 2 — Definition of joint angles for a right handed player.
throws of each participant. However, performance in our study did not describe the overall performance of each participant but the top performance (ball release speed and mean radial error of 6 selected throws) of each participant. Overall performance of each participant was determined by the percentage of missed throws relative to all throws.

Statistical Analysis

Statistical analysis was performed using SPSS ver. 16.0. software (SPSS Inc., Chicago, Illinois, USA) and GPOWER ver. 3.0.10 (University of Kiel, Germany). All variables were tested for normal distribution and means and standard deviations of the variables were calculated for descriptive statistics. To determine statistical differences between the ABOVE and SIDE throw a paired sample t test was applied to calculate significant differences for each variable. Dependent on the number of variables for each group of variables Bonferroni-correction was calculated and significance was set at $P < .0073$ for $n = 7$ variables and $P < .017$ for $n = 3$ variables. For each t test effect size (d) and statistical power ($1 - \beta$) were also calculated.

Results

Descriptive data of means and standard deviations of the variables and statistical results are presented in Table 1-3. Statistical analysis revealed that the ball release speed of the ABOVE throws was $1.4 \pm 0.8 \text{ m·s}^{-1}$ ($P < .001$) higher compared with the SIDE throws. For the throwing accuracy, we found only a marginal non-significant difference for the mean radial error ($0.01 \pm 0.01 \text{ m}$) and percentage of missed throws of $2 \pm 12\%$ (Table 1).

The kinematic analysis indicated a greater left tilt of $15 \pm 9\text{°}$ ($P < .001$) and a greater shoulder abduction angle of $7 \pm 4\text{°}$ ($P < .001$) of the ABOVE throws compared with the SIDE throws. In the timing of the maximal angles we found a significant difference between the ABOVE and SIDE throw for the trunk flexion and left tilt ($P < .001$). At ball release, significant differences were found between the two throwing techniques for the trunk flexion ($P < .001$), left tilt ($P < .001$), rotation ($P = .0072$), shoulder flexion ($P < .001$) and shoulder abduction angle ($P < .007$). The shoulder external rotation and elbow flexion angle was similar and not significantly different for both throwing techniques (Table 2).

<table>
<thead>
<tr>
<th>Variable</th>
<th>ABOVE throw Mean ± s</th>
<th>SIDE throw Mean ± s</th>
<th>$P$-value</th>
<th>Effect size d</th>
<th>Power 1 – $\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball release speed, m·s$^{-1}$</td>
<td>24.0 ± 1.3</td>
<td>22.6 ± 1.7</td>
<td>&lt; 0.001</td>
<td>1.82</td>
<td>0.99</td>
</tr>
<tr>
<td>Throwing accuracy</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Mean radial error, m</td>
<td>0.32 ± 0.08</td>
<td>0.31 ± 0.08</td>
<td>0.79</td>
<td>0.10</td>
<td>0.01</td>
</tr>
<tr>
<td>Missing throws, %</td>
<td>21 ± 7</td>
<td>23 ± 12</td>
<td>0.52</td>
<td>0.19</td>
<td>0.02</td>
</tr>
</tbody>
</table>

***$P < 0.001$. 

Table 1  Ball release speed and throwing accuracy of the team handball ABOVE and SIDE throw ($n = 12$)
For the maximal angular velocity, we found significant differences between the two throwing techniques for the trunk flexion ($P < .001$) and side tilt ($P < .001$) as well as for the shoulder flexion ($P < .001$). As shown in Table 3, the maximal angular velocity of the ABOVE throws was greater than those of the SIDE throws. For the timing of the maximal angular velocity, we found significant differences for the trunk flexion ($P < .001$) and left tilt ($P < .001$). For the angular velocity at ball release the paired sample $t$ test indicated no significant differences between the ABOVE and SIDE throws.

According to Cohen$^{14}$ we found a large effect size ($d > 0.8; 1 – \beta > 0.4$) for 19 of the variables and a moderate effect size ($d > 0.5; 1 – \beta > 0.1$) for 4 calculated variables (Tables 1–3).
Ball Release Speed and Throwing Accuracy

In the absence of studies measuring differences in ball release speed and throwing accuracy in the ABOVE and SIDE throw, we expected to find differences in ball release speed based on the experience in team handball training and competition, video observations (Figure 1A and B) and other studies in team handball.\textsuperscript{1-8} As listed in Table 1, the ball release speed was significantly greater for the ABOVE compared with the SIDE throws, whereas we found no significant differences for the

\begin{table}
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\caption{Maximal joint angular velocities, timing of maximal joint angular velocities and angular velocities at ball release in the team handball ABOVE and SIDE throw ($n = 12$)}
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\begin{tabular}{llllllll}
\hline
Variable & ABOVE throw Mean ± s & SIDE throw Mean ± s & $P$-value & Effect size & $d$ & Power & $1 - \beta$ \\
\hline
Maximal angular velocity (rad·s\textsuperscript{-1})
Trunk flexion *** & 8.0 ± 2.4 & 3.8 ± 1.7 & <0.001 & 2.68 & 1.00 & \\
Trunk left tilt *** & 5.8 ± 1.6 & 3.0 ± 1.3 & <0.001 & 1.83 & 0.99 & \\
Trunk internal rotation & 14.4 ± 1.5 & 13.9 ± 3.1 & 0.37 & 0.23 & 0.03 & \\
Shoulder flexion *** & 19.5 ± 2.3 & 16.8 ± 2.8 & <0.001 & 1.49 & 0.98 & \\
Shoulder abduction & 10.1 ± 9.8 & 9.8 ± 1.6 & 0.59 & 0.18 & 0.03 & \\
Shoulder internal rotation & 95.6 ± 22.6 & 88.7 ± 26.4 & 0.15 & 0.45 & 0.08 & \\
Elbow extension & 29.0 ± 5.3 & 27.2 ± 6.4 & 0.11 & 0.50 & 0.11 & \\

Timing of maximal angular velocity (s)
Trunk flexion *** & -0.047 ± 0.016 & -0.002 ± 0.017 & <0.001 & 1.58 & 0.97 & \\
Trunk left tilt *** & -0.096 ± 0.026 & -0.005 ± 0.044 & <0.001 & 1.59 & 0.97 & \\
Trunk internal rotation & -0.083 ± 0.018 & -0.091 ± 0.019 & 0.01 & 0.86 & 0.42 & \\
Shoulder flexion & 0.053 ± 0.003 & 0.036 ± 0.038 & 0.15 & 0.44 & 0.08 & \\
Shoulder abduction & 0.004 ± 0.005 & 0.007 ± 0.007 & 0.02 & 0.89 & 0.45 & \\
Shoulder internal rotation & 0.015 ± 0.006 & 0.019 ± 0.009 & 0.01 & 0.89 & 0.45 & \\
Elbow extension & -0.014 ± 0.004 & -0.012 ± 0.006 & 0.14 & 0.89 & 0.46 & \\

Angular velocity at ball release (rad·s\textsuperscript{-1})
Trunk flexion & 4.7 ± 2.2 & 3.4 ± 1.8 & 0.02 & 0.83 & 0.39 & \\
Trunk left tilt & 0.5 ± 2.2 & 1.1 ± 1.5 & 0.37 & 0.26 & 0.03 & \\
Trunk internal rotation & 3.1 ± 2.0 & 2.4 ± 3.0 & 0.19 & 0.43 & 0.07 & \\
Shoulder flexion & -5.7 ± 4.1 & -3.9 ± 4.0 & 0.10 & 0.53 & 0.13 & \\
Shoulder abduction & -1.2 ± 4.0 & -1.5 ± 4.9 & 0.75 & 0.01 & 0.01 & \\
Shoulder internal rotation & 81.2 ± 33.5 & 67.3 ± 32.4 & 0.03 & 0.73 & 0.28 & \\
Elbow extension & 5.0 ± 10.1 & 7.4 ± 10.1 & 0.31 & 0.31 & 0.04 & \\
\hline
\end{tabular}
\end{table}

***$P < 0.001$. 

Discussion

Ball Release Speed and Throwing Accuracy

In the absence of studies measuring differences in ball release speed and throwing accuracy in the ABOVE and SIDE throw, we expected to find differences in ball release speed based on the experience in team handball training and competition, video observations (Figure 1A and B) and other studies in team handball.\textsuperscript{1-8} As listed in Table 1, the ball release speed was significantly greater for the ABOVE compared with the SIDE throws, whereas we found no significant differences for the
throwing accuracy. Depending on the defensive strategy, team handball players use both throwing techniques in competition although the ball release speed is reduced in the SIDE throws. We postulate that the advantage of using the tactical strategy of throwing with a different arm position (6 ± 4% SIDE throws in competition) compensates the disadvantage of a reduced ball release speed.

However, the throwing accuracy was similar for both throwing techniques and may be influenced by training and competition experience of the participants. Therefore, we postulate that the difference in ball release speed was due to throwing arm dynamics and different trunk and throwing arm positions.

**Kinematic Differences**

We hypothesized that the ABOVE and SIDE throw were similar in the initial phase of the throw and differ before the ball release. As shown in Figure 3, the participant #9 in our study used similar movement patterns for both throwing techniques for the trunk rotation, shoulder flexion, abduction and rotation as well as elbow flexion (Figure 3C-G). For the trunk side tilt during arm cocking phase the movement pattern was also similar in the ABOVE as well as SIDE throw. However, the trunk flexion angle was quite different during the whole movement (Figure 3A). During the arm cocking phase, the trunk flexion angle in the SIDE throw is greater (about 30°) compared with the ABOVE throw. Depending on the throwing technique, participants in our study reached their maximal trunk flexion at significantly different times (ABOVE throw: 0.036 ± 0.040 s after ball release; SIDE throw: 0.234 ± 0.080 s before ball release). The greater trunk flexion during arm cocking phase in the SIDE throw is an important condition to achieve a greater throwing accuracy because the players are able to see the target (looking at the side of the defensive player) before the throwing movement (Figure 1B-2). In the testing situation the participants of the study threw without a defensive player but because of their experience in training (10.3 ± 3.6 y) and competition we suggest that they showed the same throwing technique as in competition, when throwing with a defensive player in place.

The arm acceleration phase generally starts 180–190 ms before ball release while participants change their movements depending on their throwing technique. As shown in Figure 3A and B, when observing the SIDE throws, participant #9 tilts his trunk to the right and backward (trunk flexion angle about –30°), while in the ABOVE throws the trunk was tilted to the left and forward 100 ms before ball release (trunk flexion angle about 10°). This specific throwing technique-dependent movement was similar for all participants and was highly significant ($P < .001$) yielding an effect size (>1.50) for the maximal trunk left tilt, timing of the maximal trunk flexion and left tilt as well as trunk flexion and left tilt angle at ball release (Table 2).

However, in the first part of the arm acceleration phase (190–100 ms before ball release) the shoulder flexion, abduction, internal rotation and elbow flexion angle was similar (difference <5°) in both throwing techniques, as shown in an example for participant #9 in Figure 3D-G and for all participants in Table 2. We suggest that team handball elite players use a general arm movement pattern with a throwing technique dependent modification in the last part of the movement.
In our participant #9, 100 ms before ball release the arm movement changed, depending on the throwing technique. In the SIDE throws the shoulder abduction angle was reduced and the shoulder flexion angle increased (Figure 3D and E). For all participants we found significant differences in the trunk left tilt and shoulder abduction angle at ball release. The combination of a reduced shoulder abduction angle and a right tilt of the trunk led to the desired hand position (the right side from the view of offensive player as shown in Figure 1B-3) at ball release. It was interesting that the difference in the angle at ball release between the ABOVE and SIDE throws was greater in the trunk left tilt (26 ± 9°) compared with the shoulder abduction (6 ± 5°). Similar differences were found for the maximal trunk left tilt (16 ± 9°) and shoulder abduction angle (7 ± 4°). The participants of our study reach the different position of the throwing arm at ball release (above head vs. side trunk) by greater differences in the movement of the trunk tilt (>25° for the trunk flexion and left tilt) and smaller differences in the movement of the throwing arm (<10° for the shoulder flexion, abduction, internal rotation and elbow flexion). Similar results were found for the difference in the maximal angles (<10° for the shoulder flexion, abduction, internal rotation and elbow flexion vs. 16 ± 9° for the trunk left tilt). We observed that the participants in our study attempted to move the throwing arm similarly in both throwing techniques (difference less than 10°).

The difference in the determined maximal throwing arm angles and angles at ball release between the two throwing techniques of the present study was smaller than the difference in shoulder abduction, internal rotation and elbow flexion between the standing throw with run-up with the throwing arm above head and the standing throw with the throwing arm above head, found by van den Tillaar and Ettema in Norwegian elite team handball players.

For the reduced trunk flexion, the last 100 ms prior, at and after ball release for the SIDE throws is important to accomplish a similar shoulder internal rotation angle as in the ABOVE throws (Figure 3F) and leads to a greater shoulder flexion angle at ball release (Figure 3D). However, we postulate that this smaller trunk flexion limits the acceleration of the trunk in the throwing direction that is evident in reduced maximal angular velocity of the trunk flexion (3.8 ± 1.7 vs. 8.0 ± 2.4 rad·s⁻¹) and different timing (−0.002 ± 0.017 vs. −0.047 ± 0.016 s) for the SIDE throws in comparison with the ABOVE throws. This limited acceleration of the trunk explains at least a partially reduced ball release speed for the SIDE throws. Wagner et al found significant differences in ball release speed (22.3 ± 1.5 vs. 18.0 ± 1.9 m·s⁻¹; $P < .001$) and maximal trunk flexion angular velocity (8.3 ± 1.7 vs. 5.6 ± 1.9 rad·s⁻¹, $p < 0.01$) between elite and low level players in team handball jump throw.

Another argument to support that the participants in our study were moving their throwing arm similarly was that we found no significant differences in the maximal angular velocities and angular velocities at ball release, except for the maximal shoulder flexion angular velocities (Table 3). However, this maximal shoulder flexion angular velocity was measured after ball release and may be influenced by the maximal trunk flexion angular velocity.

However, the limitation of the study was that we made only a kinematic analysis and measured no EMG or dynamic data, although in such dynamic movement it is very difficult to measure such data accurately. Therefore most studies in throwing analysis in team handball, baseball, American football, water polo and cricket were limited to kinematic analysis.
Figure 3 — Typical time course of the trunk flexion (A), trunk tilt (B), trunk rotation (C), shoulder flexion (D), shoulder abduction (E), shoulder rotation (F) and elbow flexion (G) angle in the team handball ABOVE (black line) and SIDE (gray line) throw. Time course are the mean + standard deviation of 6 throws for participant #9.
Shoulder Flexion

- SIDE throw
- ABOVE throw

Angle [°]

Time [s]

Shoulder Abduction

- SIDE throw
- ABOVE throw

Angle [°]

Time [s]

Shoulder Rotation

- SIDE throw
- ABOVE throw

Angle [°]

Time [s]

(continued)
**Practical Implications**

It is well known that the standing throw is the basic throwing technique in team handball and learnt in the early stages of development followed by the standing throw with run-up and jump throw. The SIDE throw is generally acquired later and separately from other throwing techniques. In team handball training players were normally instructed to abduct the throwing arm to reach the required position (side of the trunk) at ball release. The results of the study in elite team handball players showed that the proper instruction should be not to change the movement of the throwing arm but to change the position of the trunk during throwing. Specifically, the players should be coached to tilt the trunk to the right (to reach the right position at ball release) during arm acceleration.

However, the results of the study also showed that in the inertial phase of the throw the trunk and throwing arm movements are similar except for the trunk flexion. Similar movements complicate the opportunity of the rival defensive player and goalkeeper to predict the throwing technique (ABOVE vs. SIDE throw) to react appropriately, eg, to block the throw. The only possibility for the defensive player and goalkeeper to predict the throwing technique is to watch the trunk flexion of the thrower in the initial phase. In competition the throwing player should reduce the trunk flexion in the initial phase in the SIDE throw to mask the prediction of the throwing technique. Or he/she can also use this greater trunk flexion in the initial phase in the ABOVE throw to deceive the defensive player. From a practical point of view, it is important for team handball players to adapt the throw to different trunk movements. In team handball training this adaption could be learnt and optimized by throwing with different trunk movements using training methods via differential and variable training.5

**Conclusions**

The results of this study indicate that the different position of the hand at ball release of the ABOVE and SIDE throws is primarily caused by different trunk flexion and tilt angles that lead to differences in ball release speed but not in throwing accuracy,
and that the participants attempted to move their throwing arm similarly in both throwing techniques.

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